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Effects of Modes on THz Wireless Channels Inside Metal Enclosures

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Abstract

This paper studies the effects of the geometrical parameters of the rectangular metallic enclosure on the THz wireless link. Three rectangular conducting cavities of different sizes are fabricated and tested to explore the feasibility for THz wireless link. The dimensions of the boxes are selected to represent the physical sizes of the computer desktops. Measurements show that the mode interference and hence multipath depend upon the transverse dimensions of the cavity. Furthermore, for the same excitation, it is shown that due to the large value of the fractional frequency changes the smaller cavity has less path loss variation and reduced multipath.

1 Introduction

Data communications between the components inside the computing devices presently operate through wire connections which pose a limitation on further scaling as the interconnects are not proportional with the transistor scaling. Wireless interconnects at THz frequencies are preferred [1], [2]. To enable the communication, THz wireless channel characterization and modeling in practical scenarios are required. On-board THz wireless communication channel characterization has been conducted in [3]. Also, measurements have been collected inside the rectangular metallic cavity which resembles the practical computer desktops [4]. It is found that both traveling wave and resonant modes exist inside the metal cavity. Based on this finding, a path loss model which consists of the traveling wave loss, resonant modes-based power variation, and the loss due to the radiation pattern of the directional antennas has been proposed in [5]. For short range wireless communications between on-board components, a statistical channel model has been proposed in [6].

As an extension of the previous works, this paper presents the effects of the geometrical parameters of the cavity on the THz wireless link inside the cavity. It is shown that the larger cavity dimensions will lead to larger path loss variation over the frequency band and more pronounced multipath as compare to the smaller cavity.

The remainder of the paper is organized as follows. Section 2 briefly describes the measurement scenarios and measurement setup. Section 3 discusses the mode sensitivity. Section 4 shows an analysis of the measured results. Section 5 provides concluding remarks.

2 Measurement Scenarios

This section describes the measurement setup and scenarios used in this study. Measurements performed in [4] demonstrate the propagation mechanism in a desktop size metal cavity. In this paper, we consider the effects of the cavity size on the wireless channel by taking the measurements in cavities with different dimensions. For the first measurement, a new cavity was built by reducing the width of the desktop size cavity described in [4] to 10 cm. Measurement was performed with the height of transceivers, h, equals 2.4 cm. Please note that, h represents the distance between the bottom of the cavity and the phase center of the transceivers. For the second measurement, another metal cavity was built by reducing the height of the desktop size cavity to 5 cm, which is close to the size of a rugged laptop as shown in Fig. 1 (left). The measurement, again, was performed with h = 2.4 cm. As shown in Fig.1 (right), the last measurement was performed in a metal cavity whose size is close to Intel-NUC mini-desktop (11 cm × 11 cm × 5cm) with h = 2.4 cm. All measurements were performed in empty metal cavities with only LoS propagation being considered.

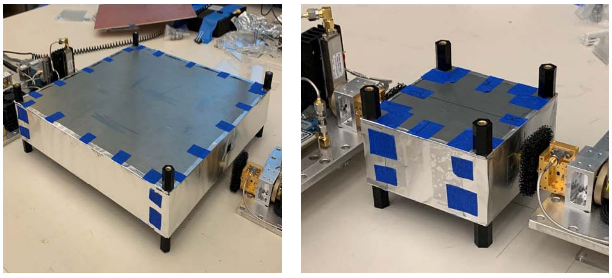

Figure 1. Rectangular metallic cavities used in measurements (left) larger cavity of dimension 30.5×30.5×5cm (right) small cavity 11×11×5cm.

3 Mode Sensitivity

It is well known that fields are sensitive to geometrical and excitation parameters. We assume that for all the cases described in the paper, there is a small effect of excitation parameters. This stems from the fact that the source and receiver are the diagonal horn and are mounted on cavity sidewalls in all the cases as shown in Fig. 1. Hence it can be stated that the changes in the channel parameters will only be attributed to the geometrical parameters of the cavity. Alternatively, this shows the resonant modes effects on the THz wireless link. For the electrically large cavity of given volume V, the number of modes can be approximated as [7]:

$$N(f) \approx \frac{8\pi f^3 V}{3c^3}. \quad (1)$$

For a given frequency, the total number of modes depends upon volume of the cavity for which the frequency sensitivity can be calculated as;

$$\frac{\Delta f}{f} = \frac{\lambda^3}{8\pi V}, \quad (2)$$

where λ is the free space wavelength. For the cavities shown in Fig. 1, the Δf at 300GHz is 2.56 and 19.71 KHz respectively. Larger value of Δf for the smaller cavity points to the less mode interference and consequently less path loss variation with frequency.

4 Results and Discussion

This section presents the measured path loss and PDP's results for the cavity shown in Fig. 1. In [4], we characterize the THz wireless link in the metallic cavity with dimension of 30.5×30.5×10 cm. Here we vary the width and the thickness of the cavity to explore the effects on wireless link. Fig. 2 shows the path loss vs frequency and PDP when the width is reduced to 10cm, i.e. the cavity dimension is 30.5×10×10 cm. The result shows the stronger multipath. While the average path loss behavior over the band can be explained by the path loss model proposed in [5], the path loss at a particular frequency depends upon modes density and interference at that frequency. Due to larger cavity volume, the frequency change between the adjacent modes is less as explained in Section 3 and hence results in larger variation of the received power.

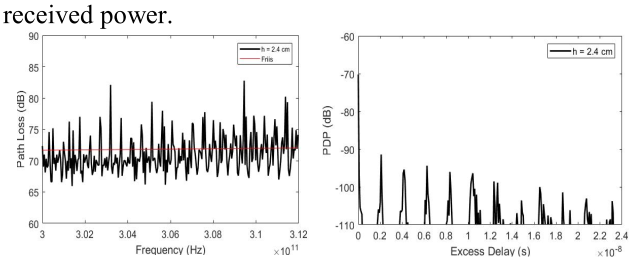

Figure 2. (left) Path loss vs frequency and (right) measured PDP for a cavity with the dimension of 30.5 cm × 10 cm × 10 cm.

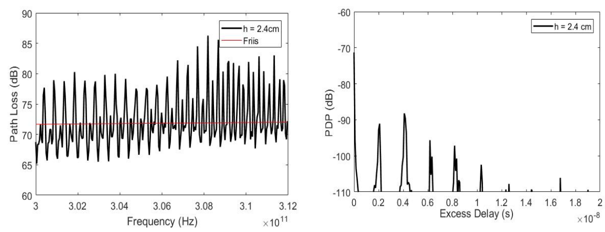

Figure 3. (left) Path loss vs frequency and (right) measured PDP for a cavity with the dimension of 30.5 cm × 30.5 cm × 5 cm.

Fig. 3 shows the path loss and PDP when the height is reduced to 5 cm i.e., for the cavity dimension 30.5×30.5×5cm. We can note that this reduction does not have significant effect on the number of multipath but has a stronger variation in path loss as compared with the height of 10 cm [4]. This can be explained by the wave guiding effect of the travelling wave bouncing from the top and side walls which results in constructive and destructive interference at the receiver location.

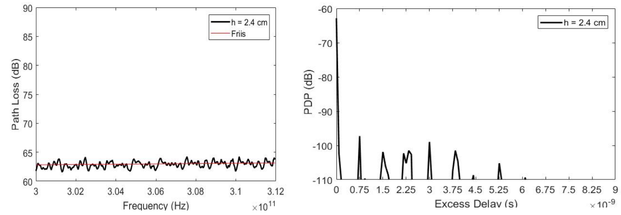

Figure 4. (left) Path loss vs. frequency and (right) measured PDP for a smaller size box shown in Fig. 1.

In the third case mentioned in Section 2, we reduced the transverse dimension to 11cm i.e., the cavity dimension is 11×11×5 cm. The measured path loss and PDP is shown in Fig.4. Due to smaller distance between the antennas the average path loss is reduced. We also note that the path loss variation with frequency is limited to 2 dB as compared to∼ 20 dB in the larger cavity sizes. One possible reason for this is the increase in the relative frequency sensitivity as explained in Section 3. Also, the PDP has less multipath signal amplitude. It is to be noted that, the distance between the source and the receiving antenna is 11 cm compared to 30.5 cm in the larger cavity and may have some near field effects.

5 Conclusions

The effects of geometrical parameters on the THz wireless channel inside a metallic resonant cavity was presented. We demonstrated that the small size cavity has less path loss variation and less multipaths due to increase in the frequency sensitivity.

6 References

1. S. Priebe, C. Jastrow, M. Jacob, T. Kleine-Ostmann, T. Schrader and T. Kürner, "Channel and Propagation Measurements at 300 GHz," in *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 5, pp. 1688-1698, May 2011.
2. T. Kleine-Ostmann, C. Jastrow, S. Priebe, M. Jacob, T. Kürner and T. Schrader, "Measurement of channel and propagation properties at 300 GHz," *2012 Conference on Precision electromagnetic Measurements*, Washington, DC, 2012,
3. S. Kim and A. Zajić, "Characterization of 300-GHz Wireless Channel on a Computer Motherboard," in *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 12, pp. 5411-5423, Dec. 2016. doi: 10.1109/TAP.2016.2620598.
4. J. Fu, P. Juyal and A. Zajić, "THz Channel Characterization of Chip-to-Chip Communication in Desktop Size Metal Enclosure," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 12, pp. 7550-7560, Dec. 2019. doi: 10.1109/TAP.2019.2934908.
5. J. Fu, P. Juyal, and A. Zajic, "Investigation of resonance based propagationloss modeling for thz chip-to-chip wireless communications," in 14th *European Conference on Antennas and Propagation* (EuCAP). IEEE, 2020, pp. 1–5.
6. S. Kim and A. Zajić, "Statistical Modeling and Simulation of Short-Range Device-to-Device Communication Channels at Sub-THz Frequencies," in *IEEE Transactions on Wireless Communications*, vol. 15, no. 9, pp. 6423-6433, Sept. 2016. doi: 10.1109/TWC.2016.2585103
7. D. A. Hill, Electromagnetic Fields in Cavities. Hoboken, NJ, USA:Wiley, 2009.